Very short-term forecast of wind speed and power at the offshore wind farm Global Tech I using horizontal PPI lidar scans

F. Theuer[1], L. Valldecabres[1], L. von Bremen[2], M. Kühn[1]

1. ForWind, Institute of Physics, University of Oldenburg, Germany

2. DLR Institute of Networked Energy Systems, Germany

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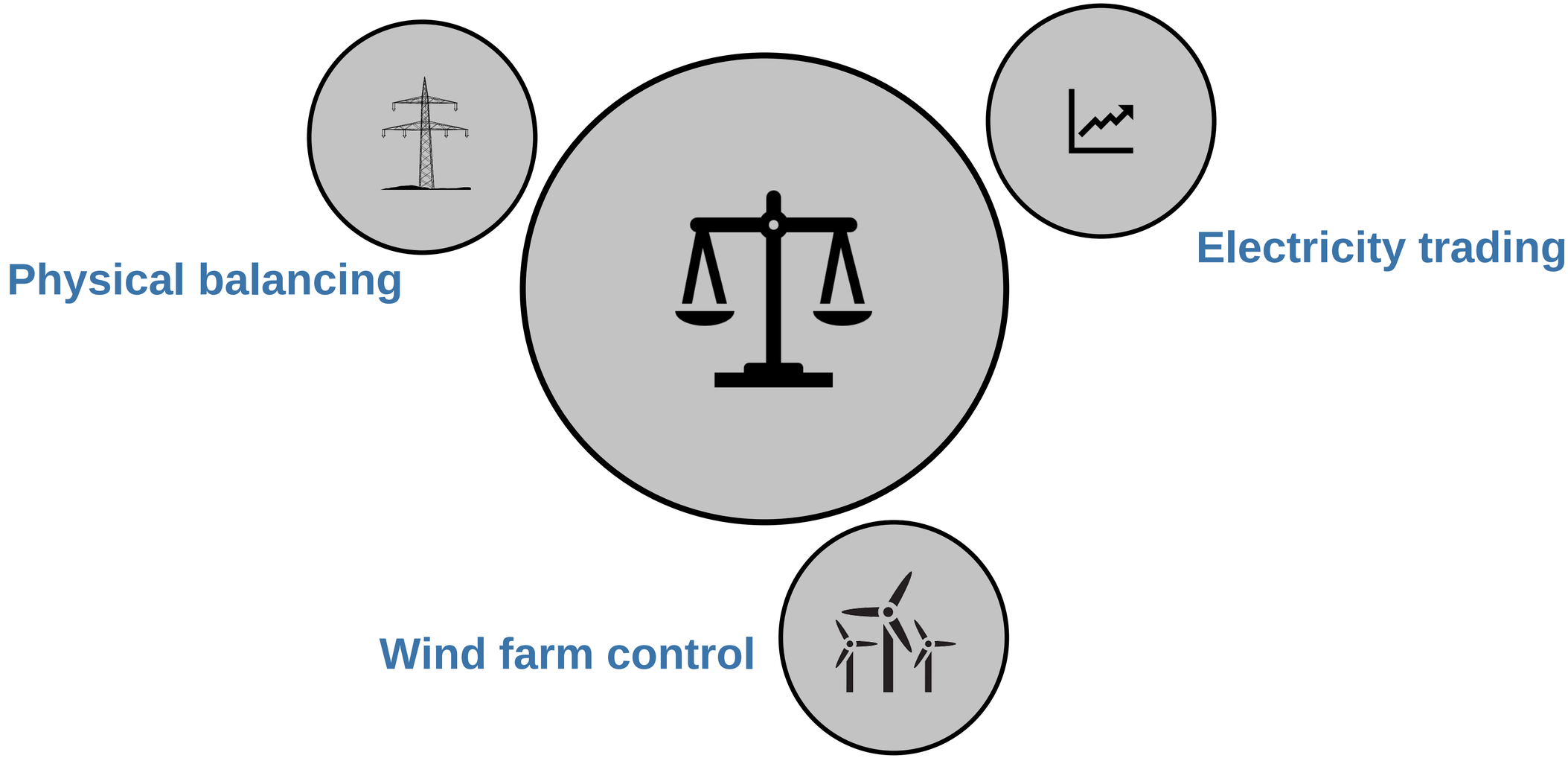
Why very short-term power forecasts?



Very short-term power forecasts – State of the art

Statistical methods:

- Low quality for rare events (i.e power ramps)
- Benchmark persistence:
  - „What you see is what you get“

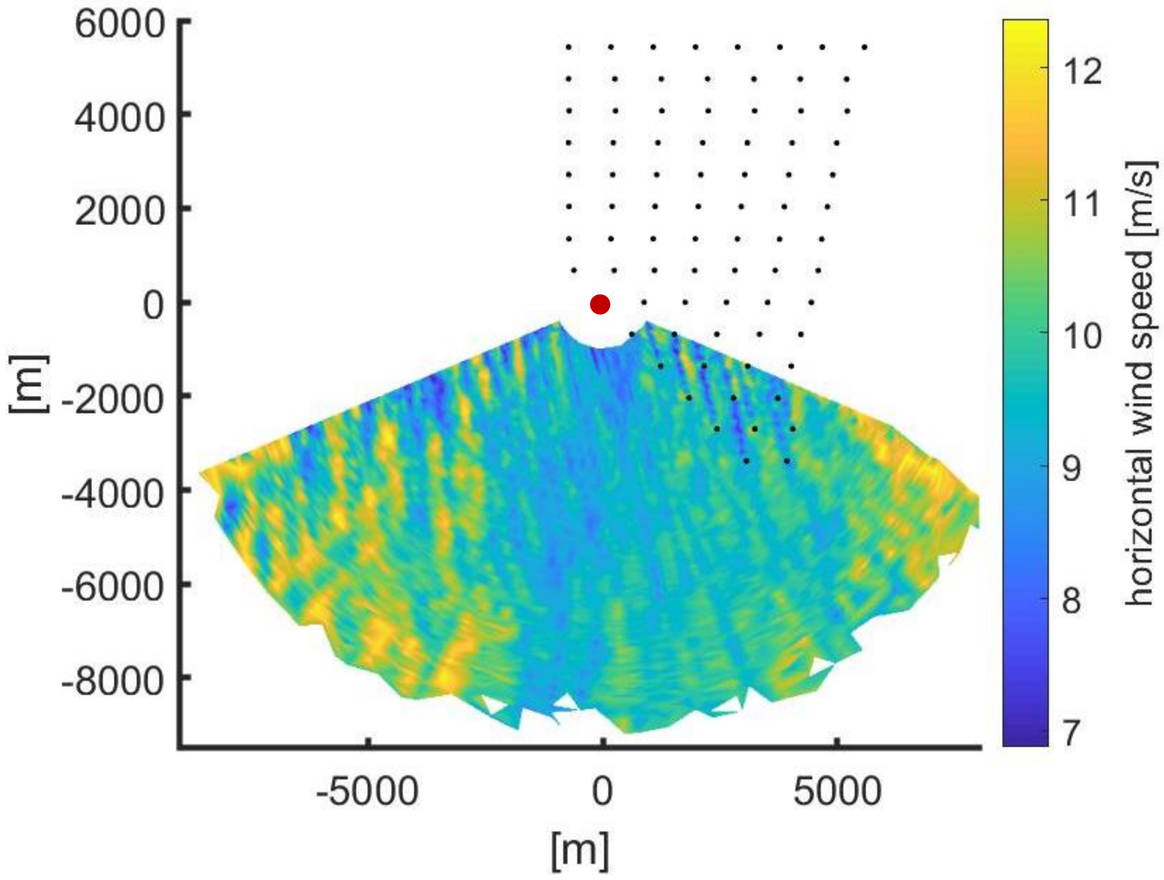
Remote sensing forecasts:

- Very short-term forecast based on physical method
- Measure incoming flow in long distances
- Current research shows promising results

Can horizontal long range lidar measurements be used to forecast power with lead times of 5-15 minutes?

Lidar Measurements at Global Tech I

- Offshore wind farm Global Tech I located in the German North Sea
- Horizontal Plan Position Indicator (PPI) Lidar Scans
- Range gates from 1000m to 12000m with spacing of 50m
- Averaging time per measurement 8s
- Azimuthal resolution 2°
- Azimuth spanned 150°
- Time per scan 600s



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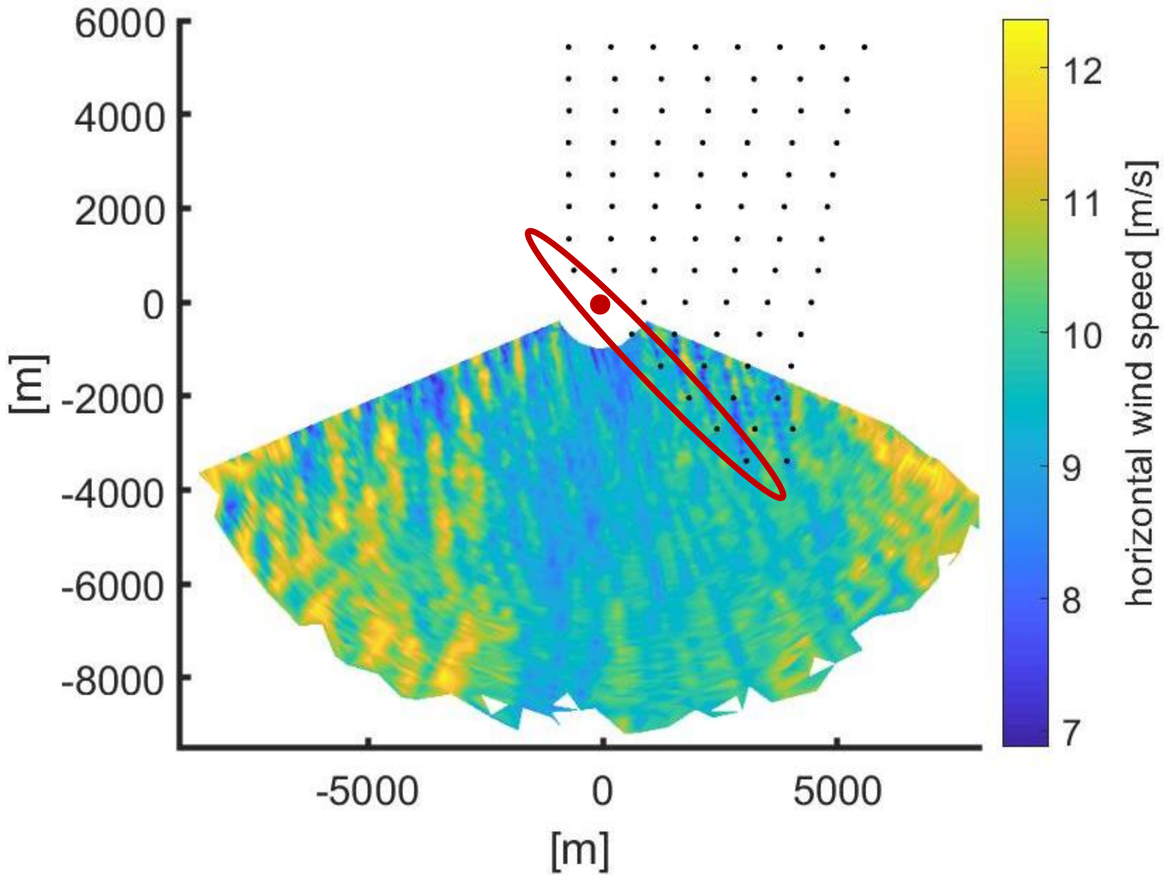

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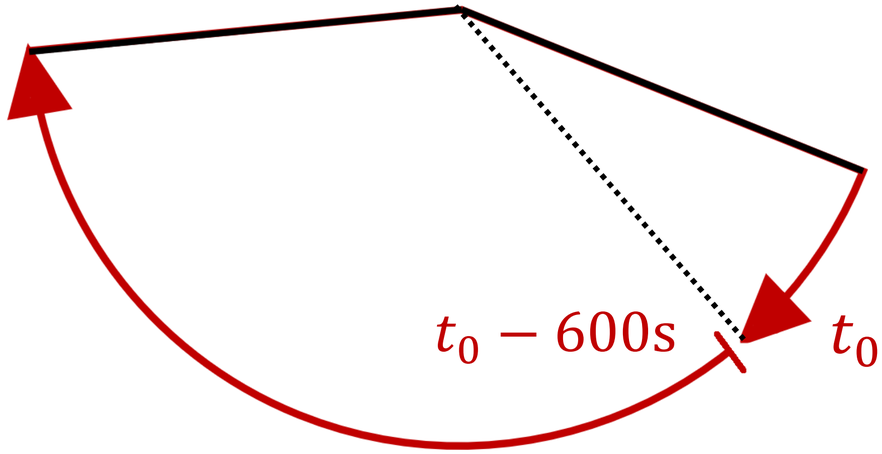
Lidar Forecast Methodology

Wind Speed Reconstruction

Velocity Azimuth Display (VAD) fit:

- Individually for each range gate
- Time interval $[t_0 - 600s, t_0]$ used for VAD fit



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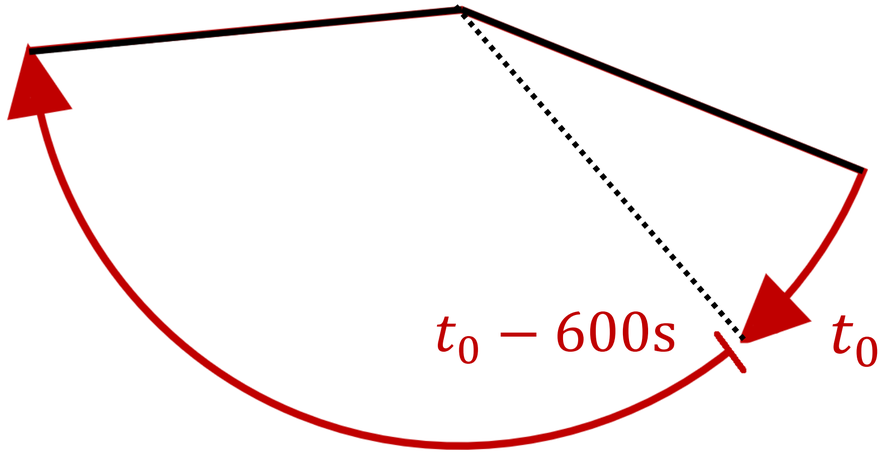
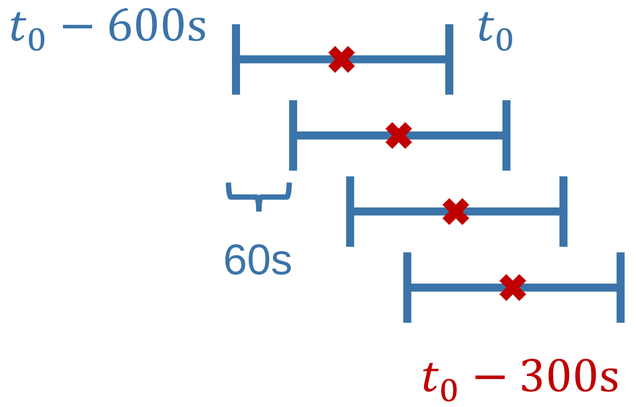
- „Moving-average“ approach





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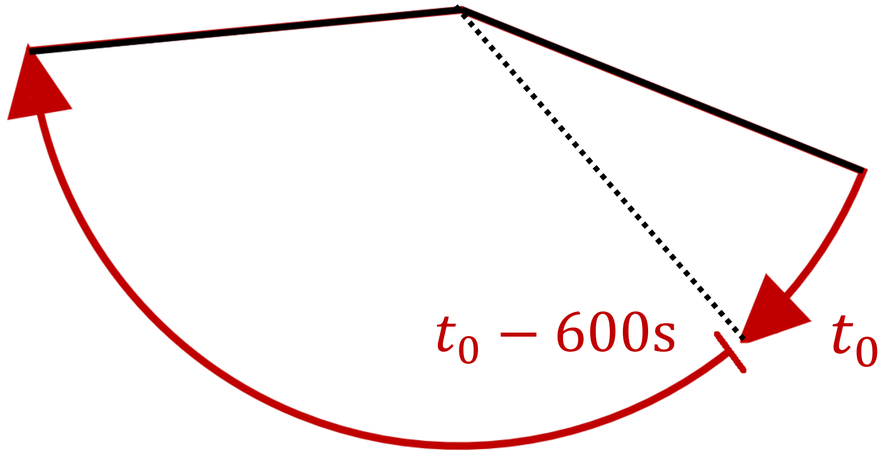
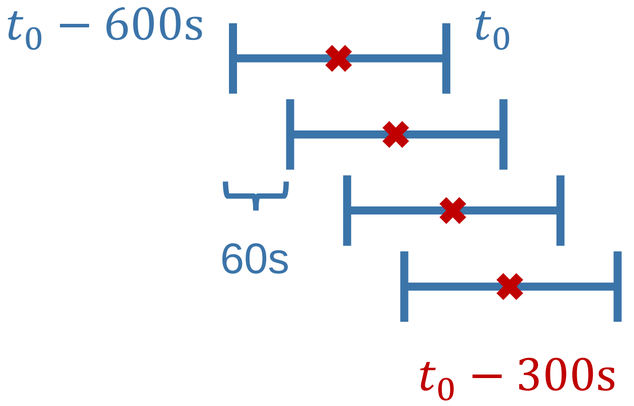
→ Wind speed and wind direction time series with 60s resolution for each range gate





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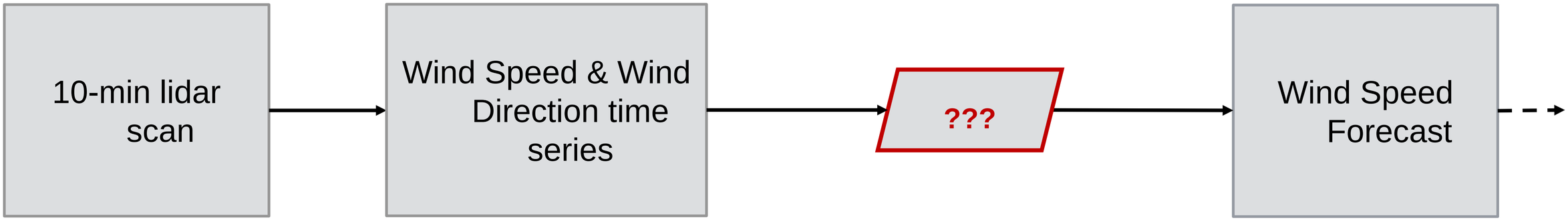
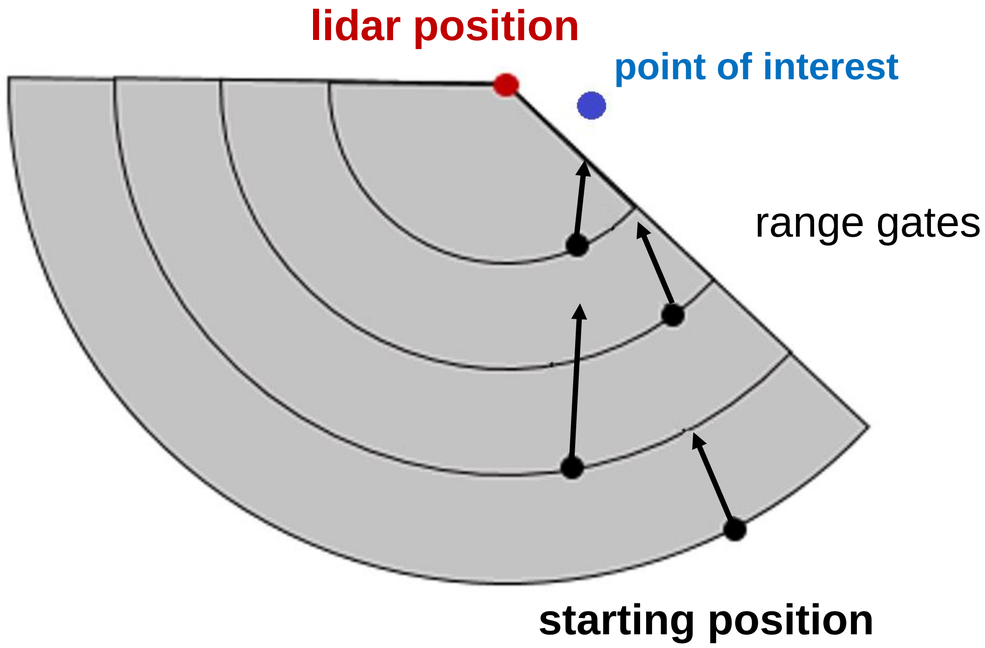


Wind Vector Propagation

- 1 wind vector per range gate and time step
- Lagrangian advection technique:
  - **Each vector travels with its local wind speed and direction**



- Starting position of each vector
- Distance between starting position and point of interest
- Time of arrival at the point of interest

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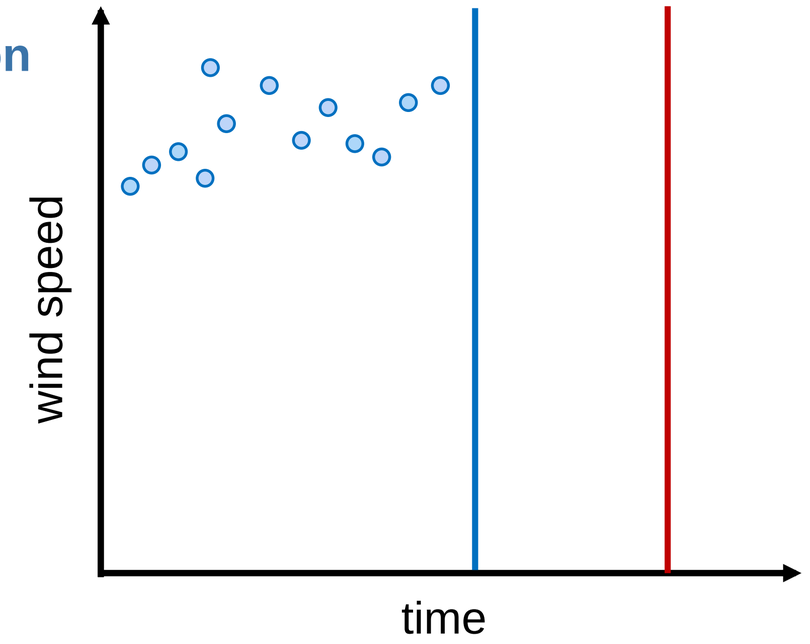

issue of forecast

forecasted time

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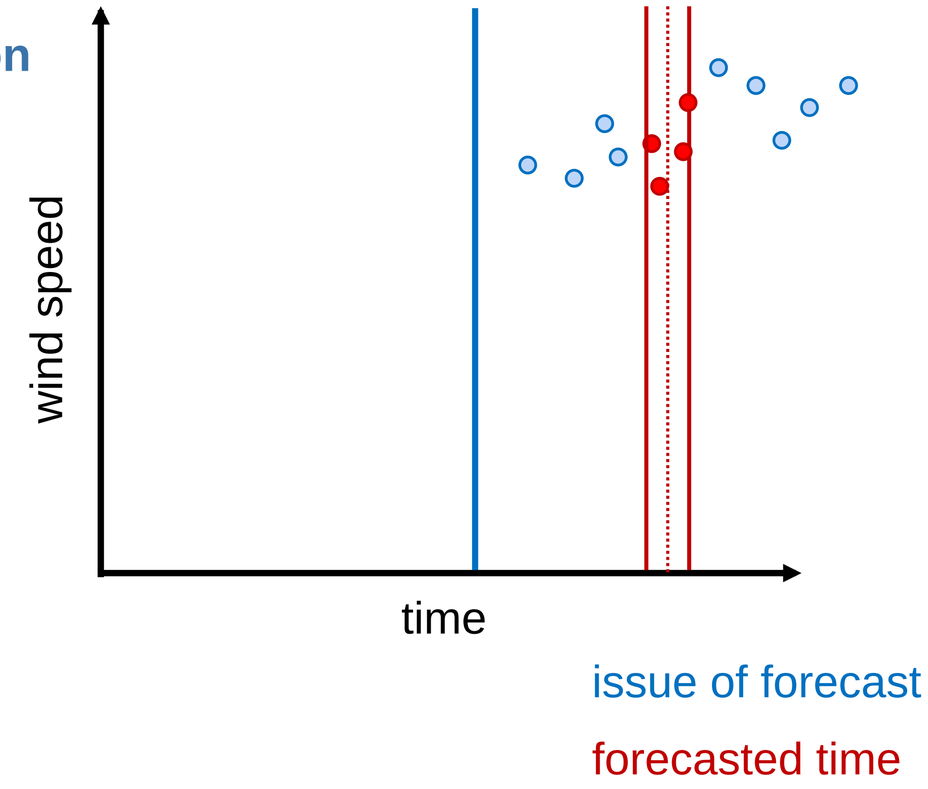

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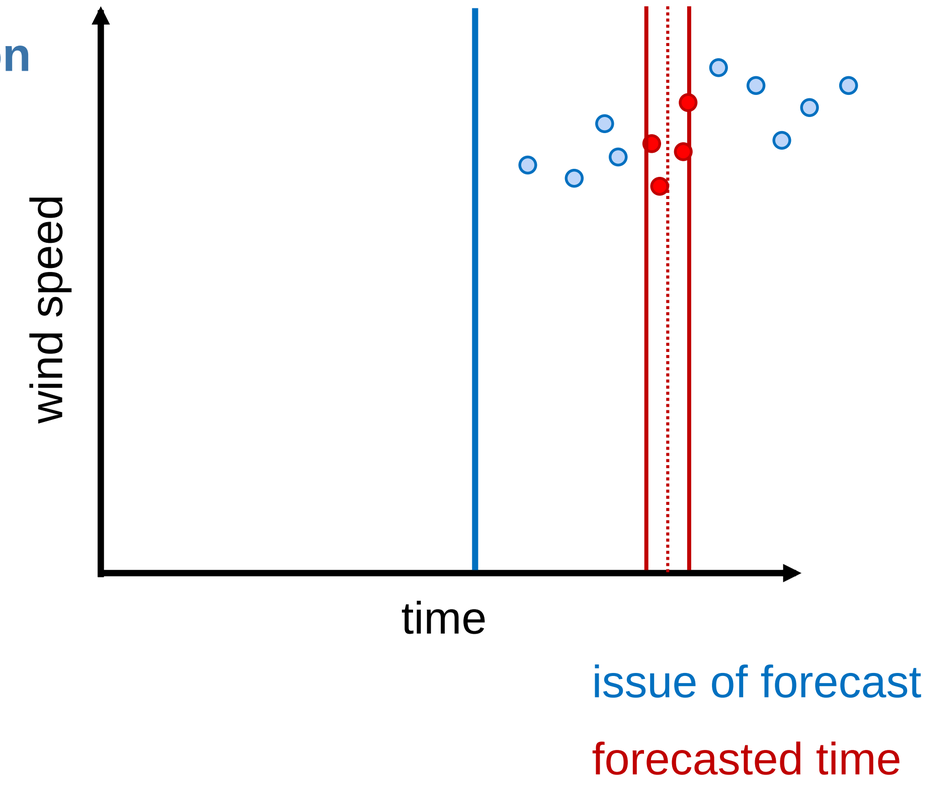

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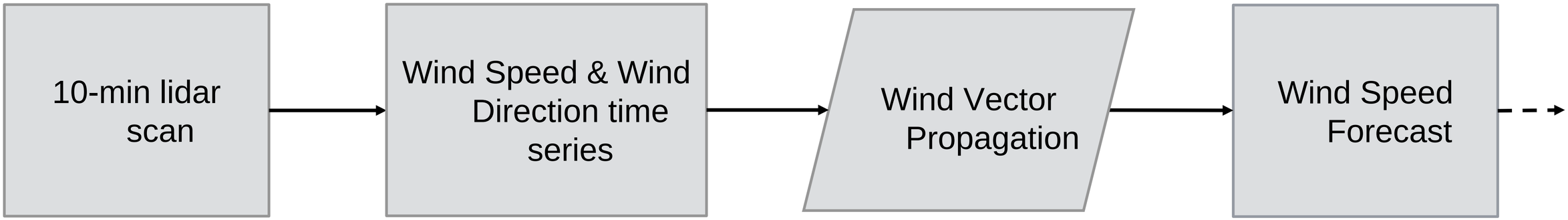
→ **Wind speed forecast**

Lidar Forecast Methodology



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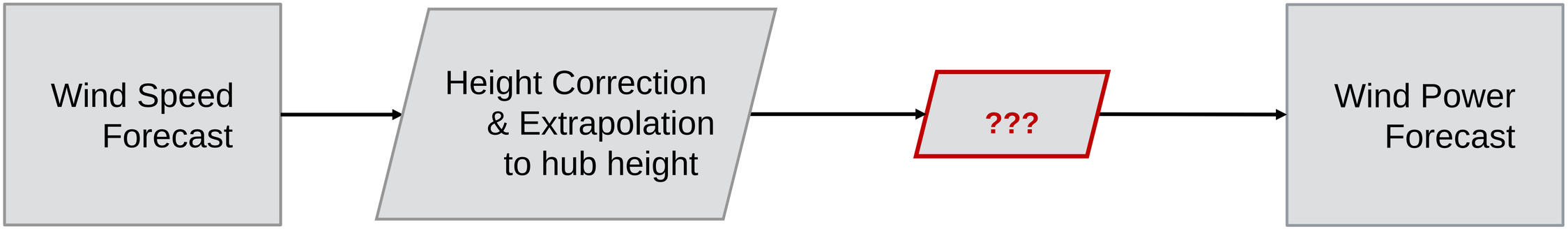

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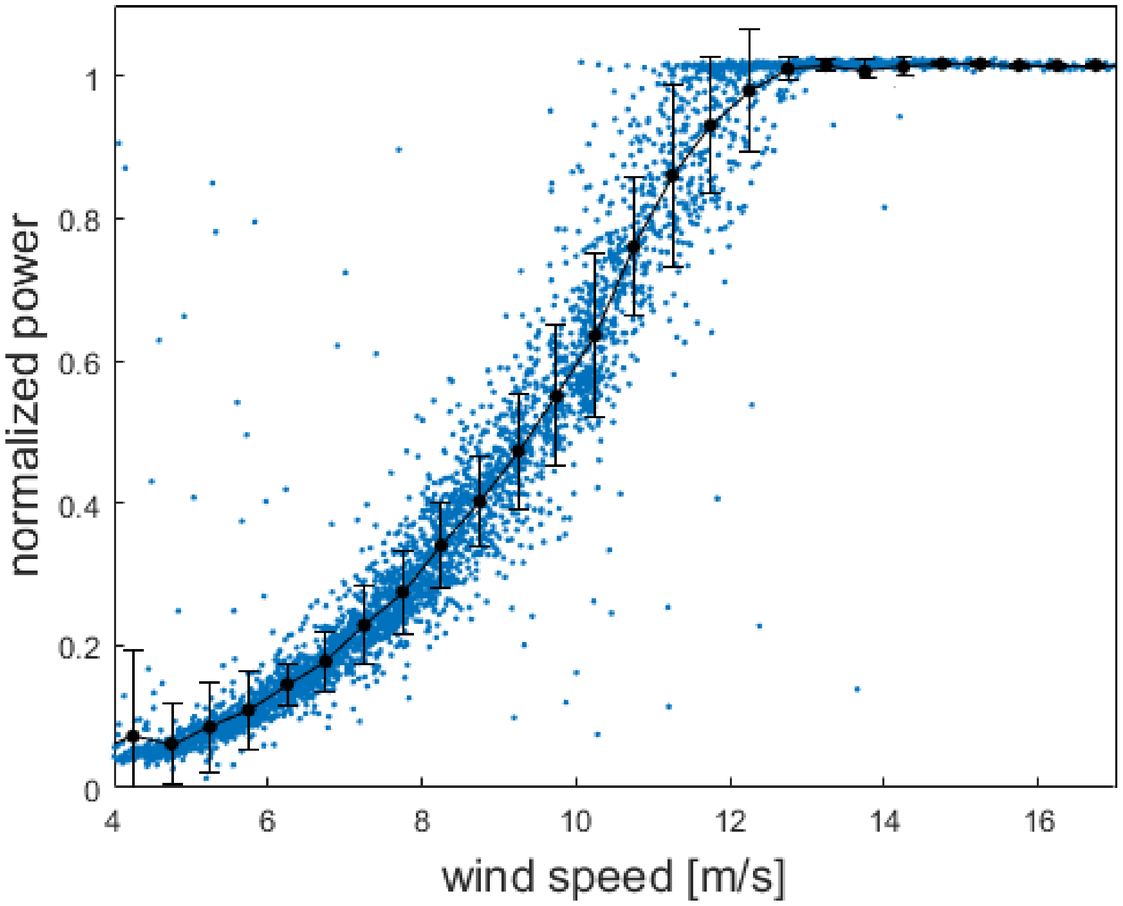
Probabilistic Power Curve

- Determining probabilistic power curve based on high elevation lidar scans and SCADA power data
- Power in each wind speed interval is described using mean power and its standard deviation
- Bootstrapping algorithm to transform wind speed distribution to power distribution
- Deterministic power forecast as mean value of distribution



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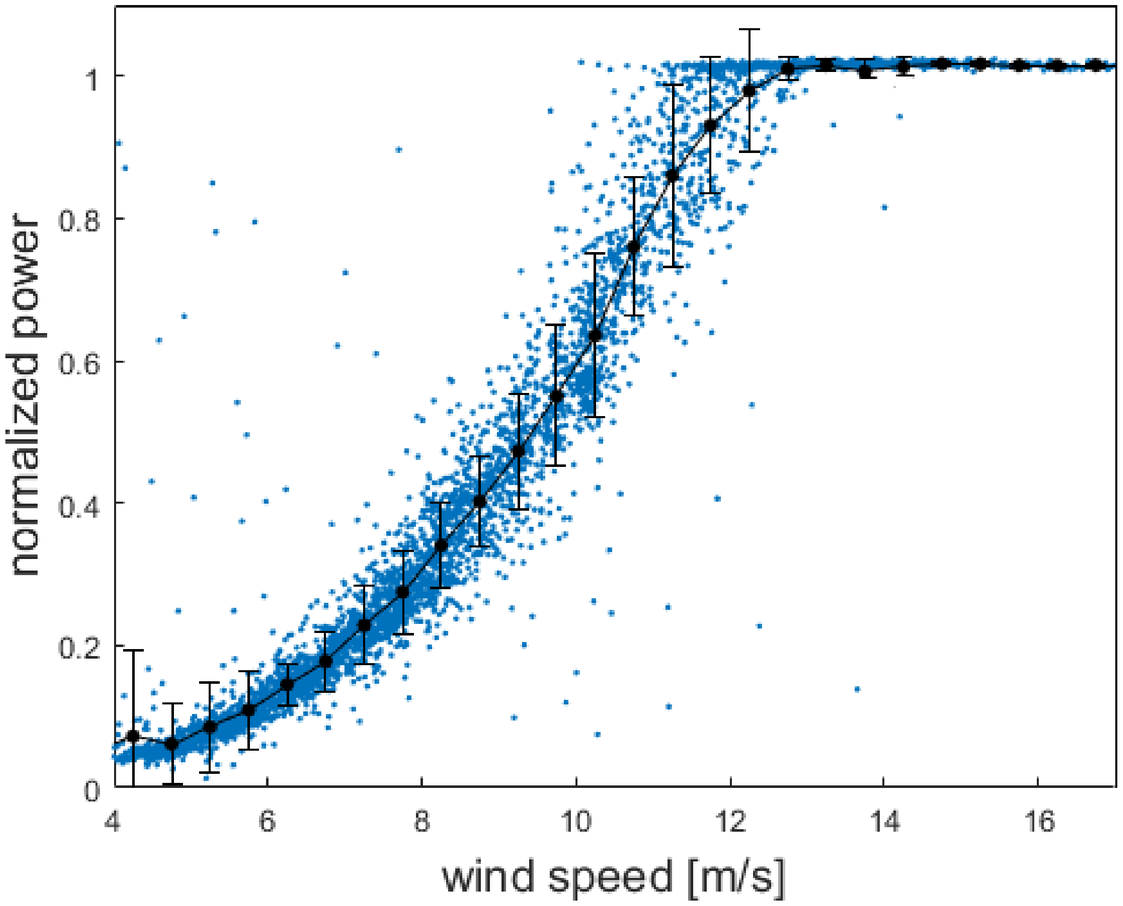

→ **Wind power forecast**

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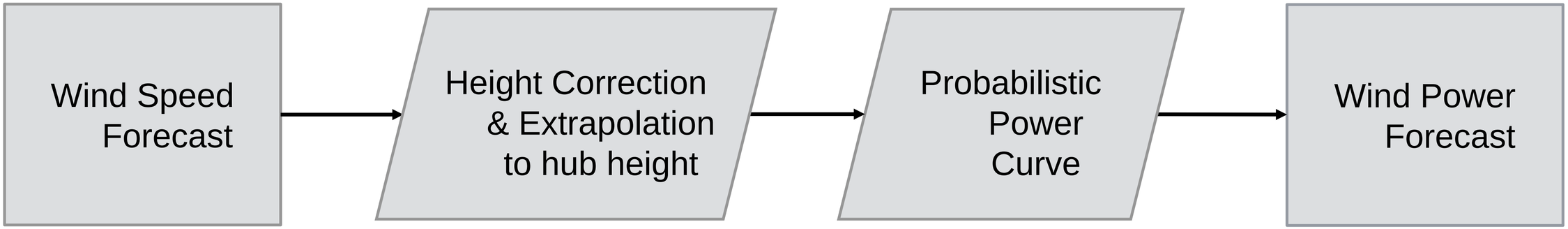
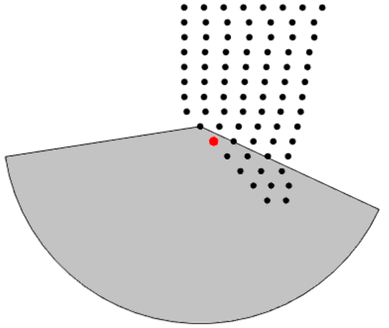
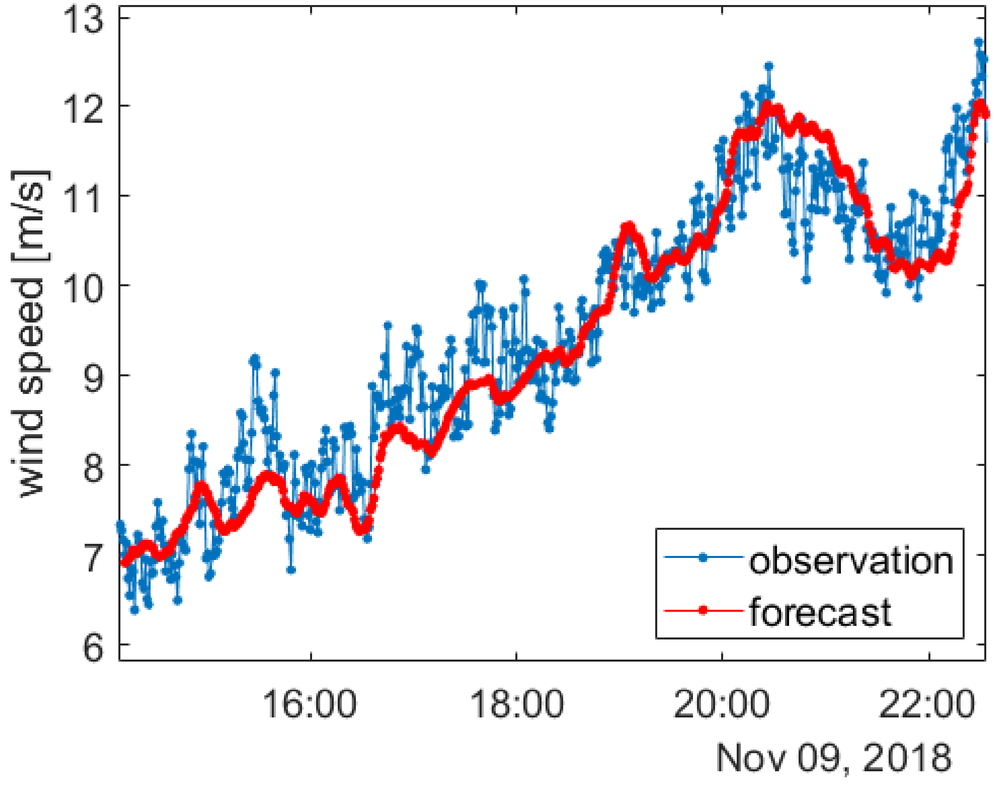


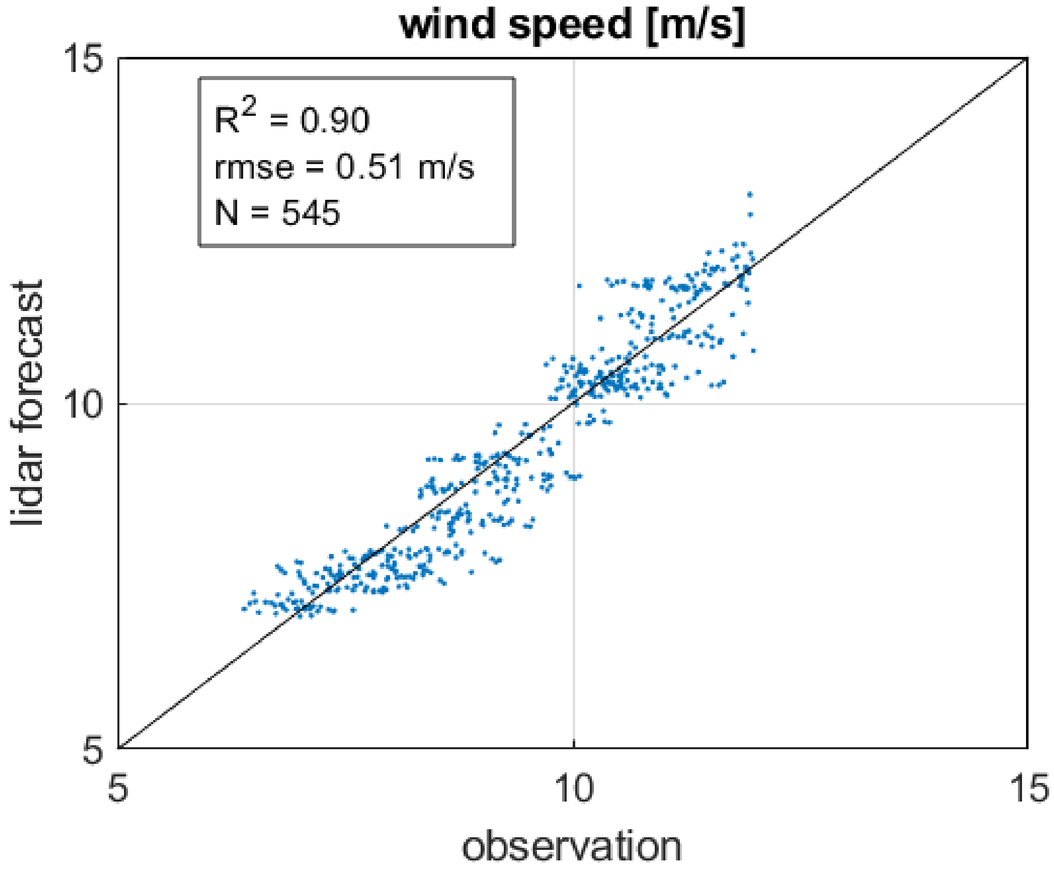
Forecast Evaluation



5-minute-ahead wind speed forecast

Individual turbine





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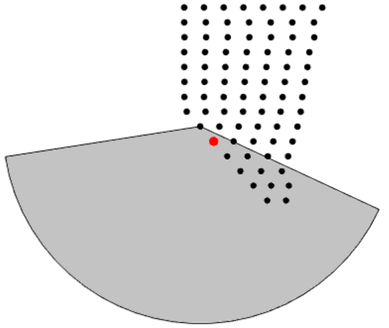

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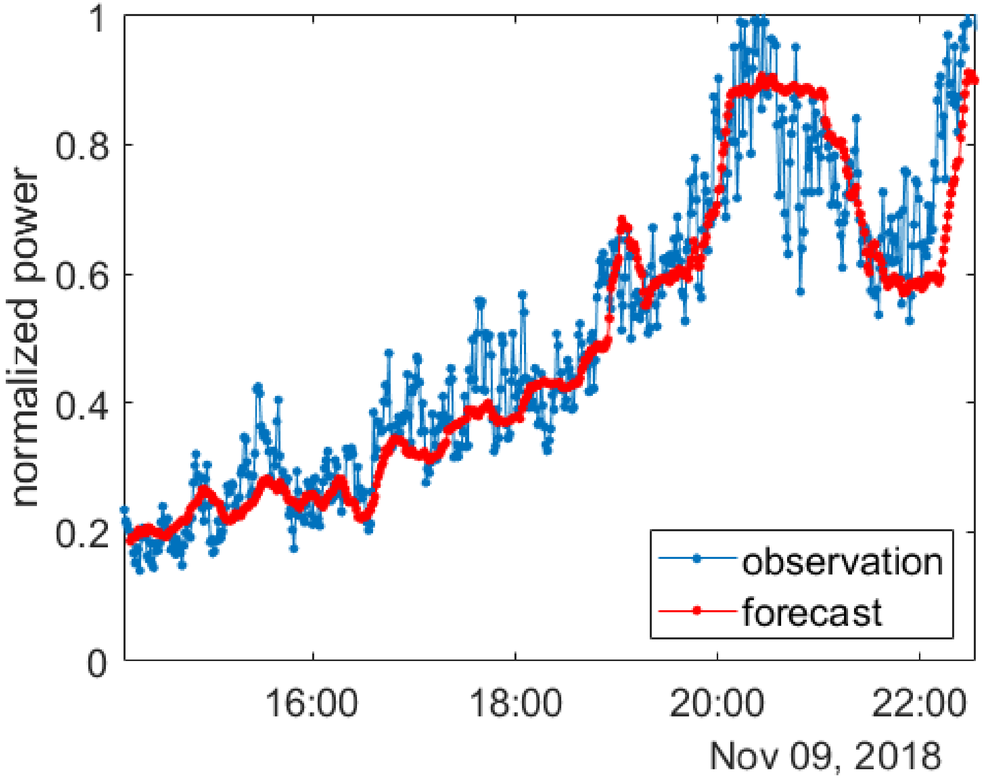

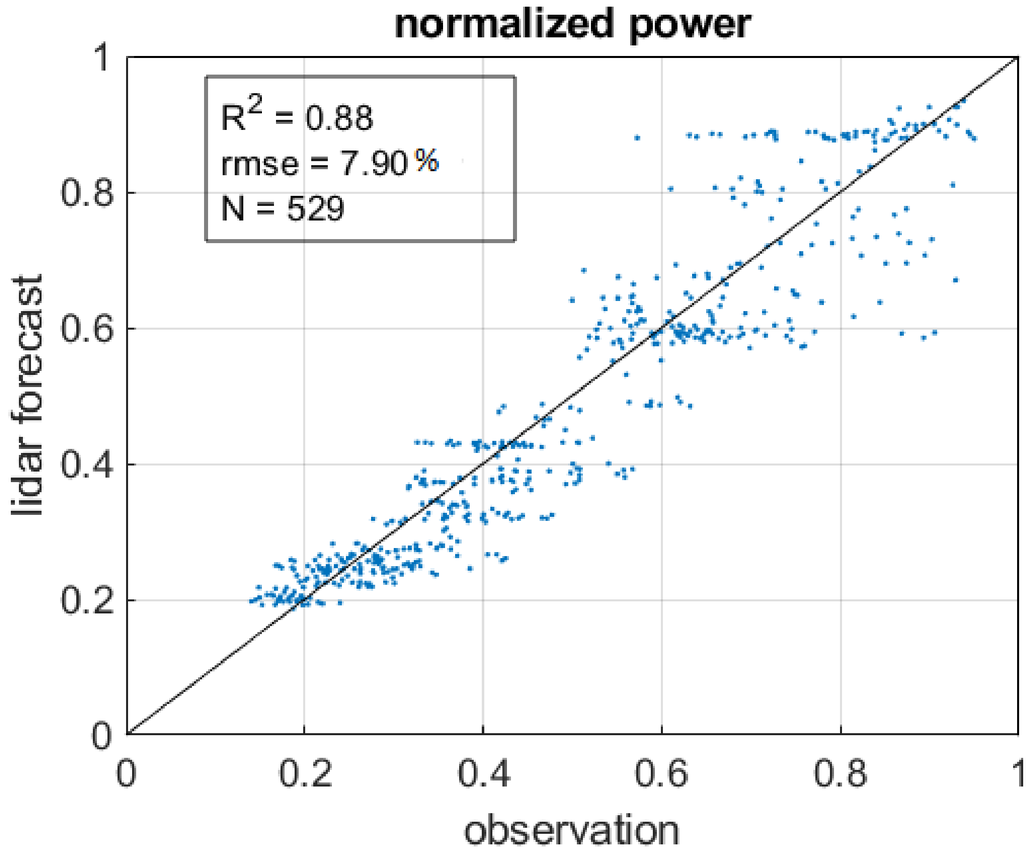

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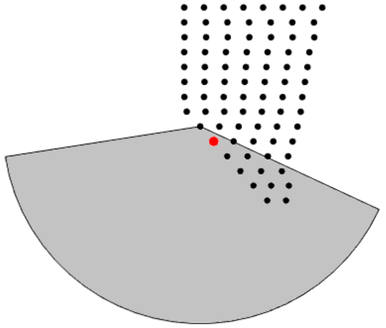

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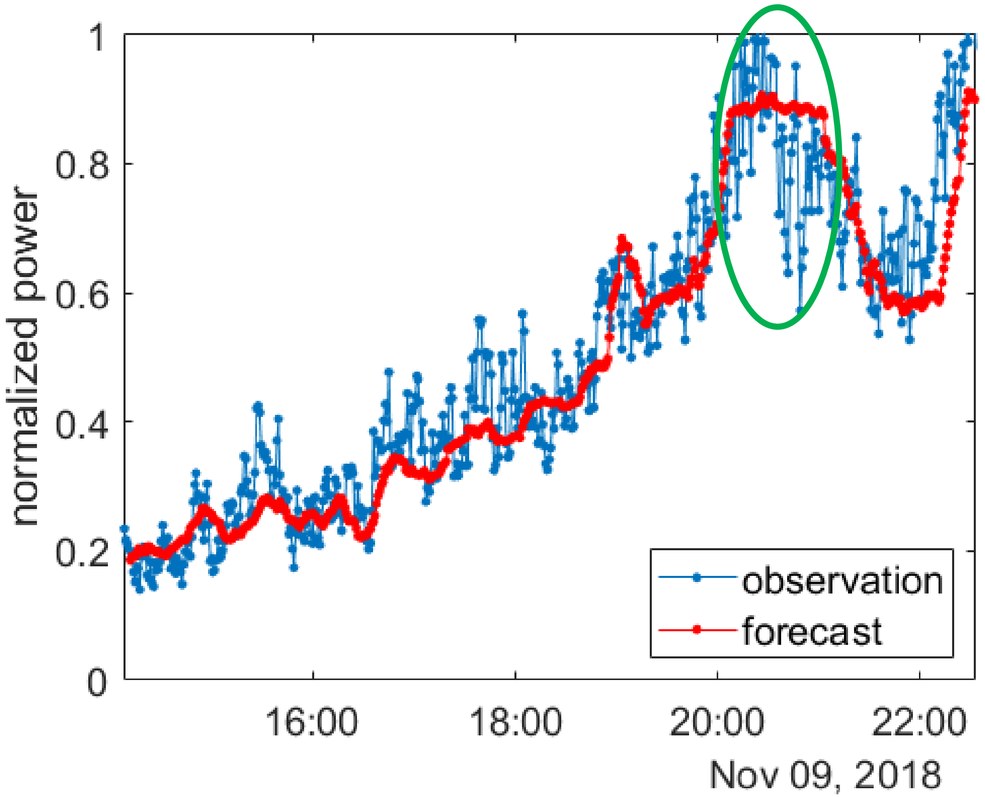

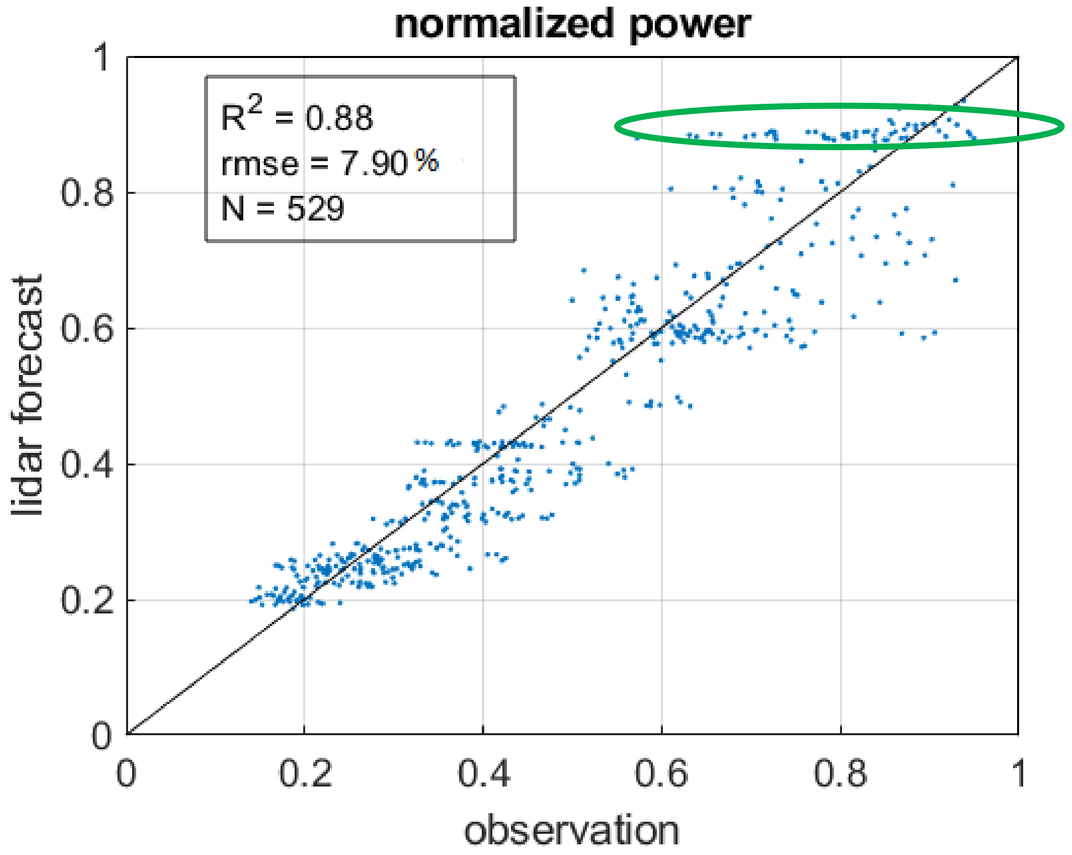

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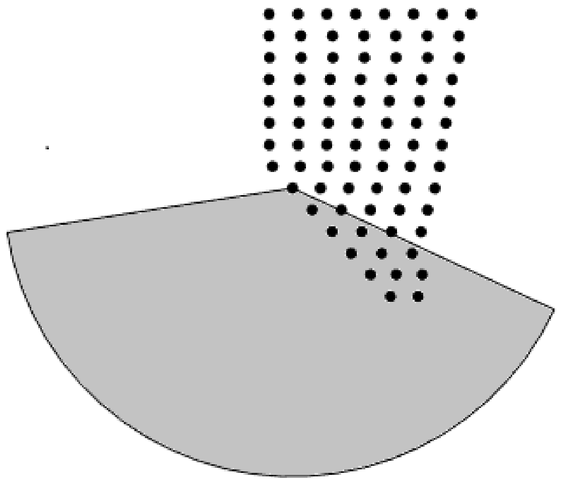
Forecast Evaluation

- The lidar forecast outperforms persistence:
  - Root Mean Squared Error (rmse) and Mean Absolute Error (mae)
  - All first row turbines
  - Wind speed and power forecast

- The lidar forecast shows a slightly larger bias than persistence
- The lidar forecast cannot predict strong fluctuations
- The availability of the forecast is limited by wind speed and turbine position



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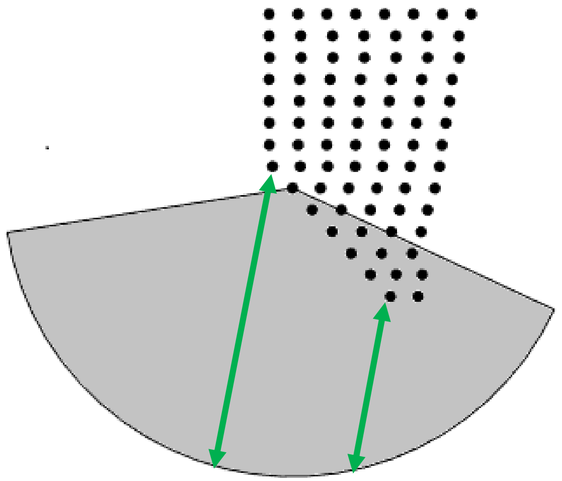

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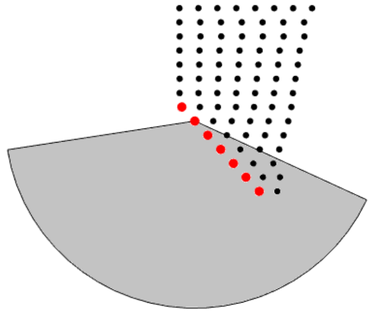
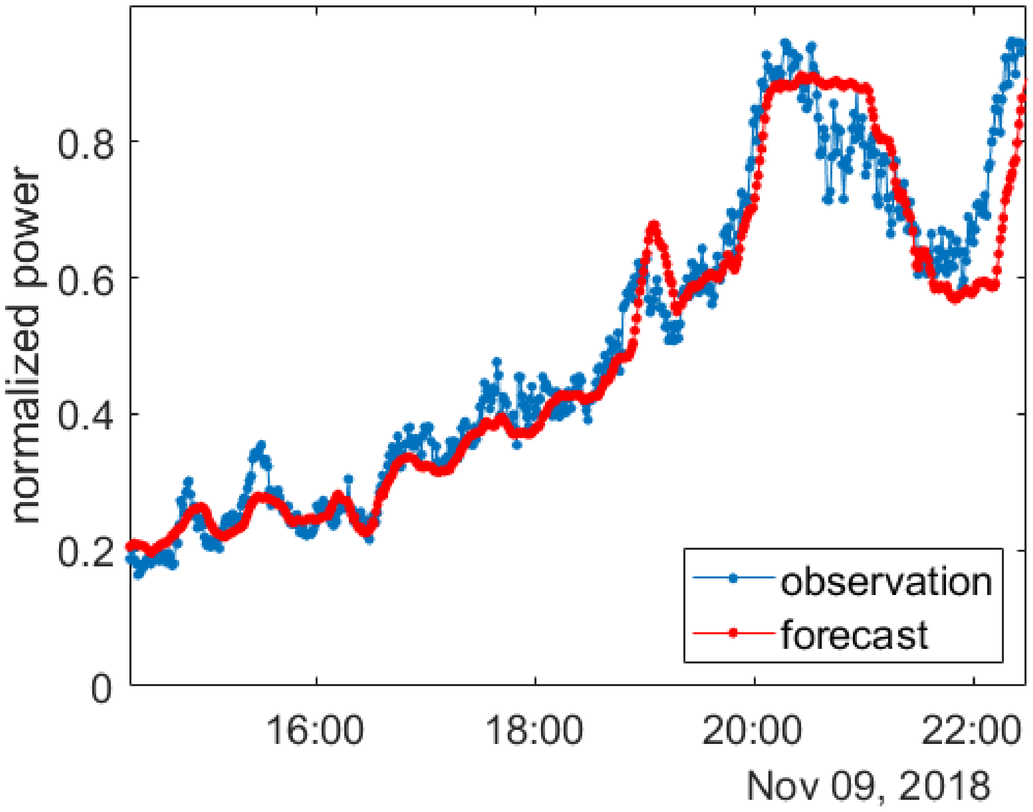
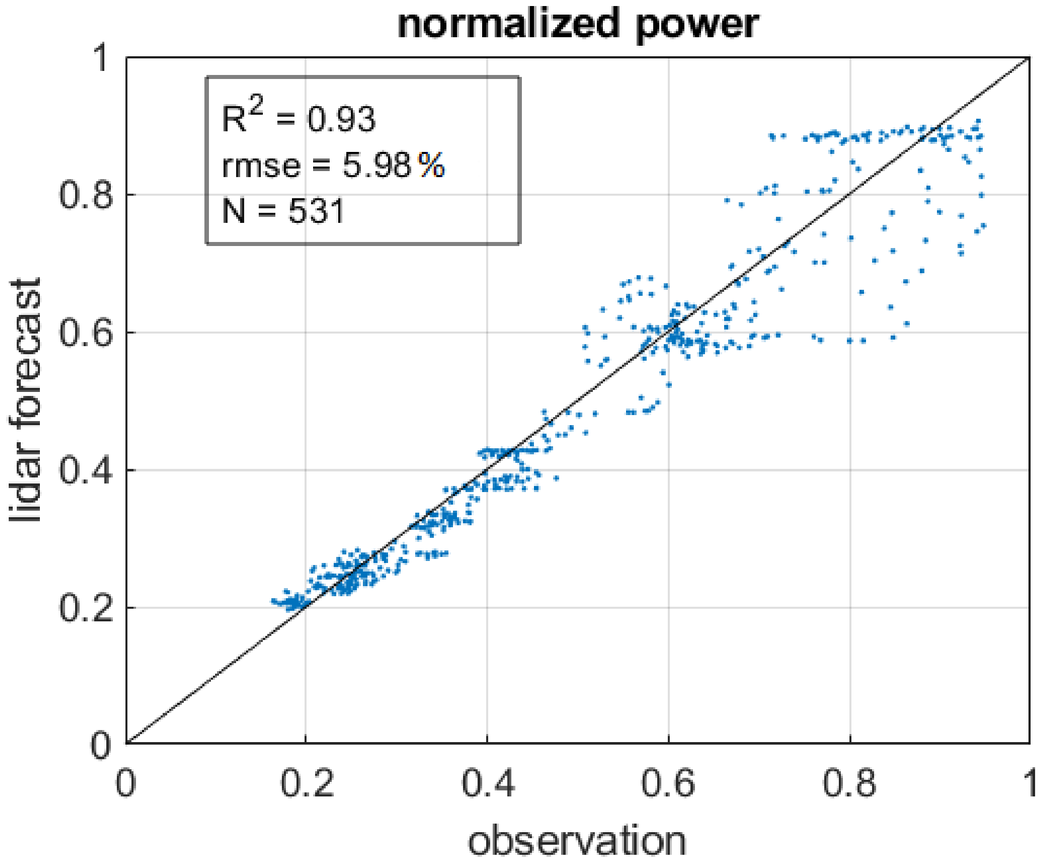


5-minute-ahead power forecast

Aggregated turbines





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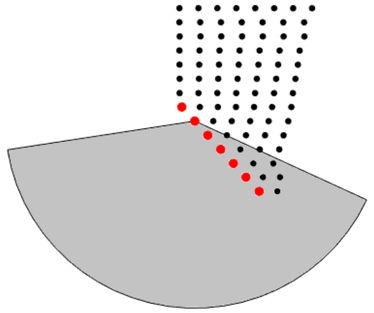

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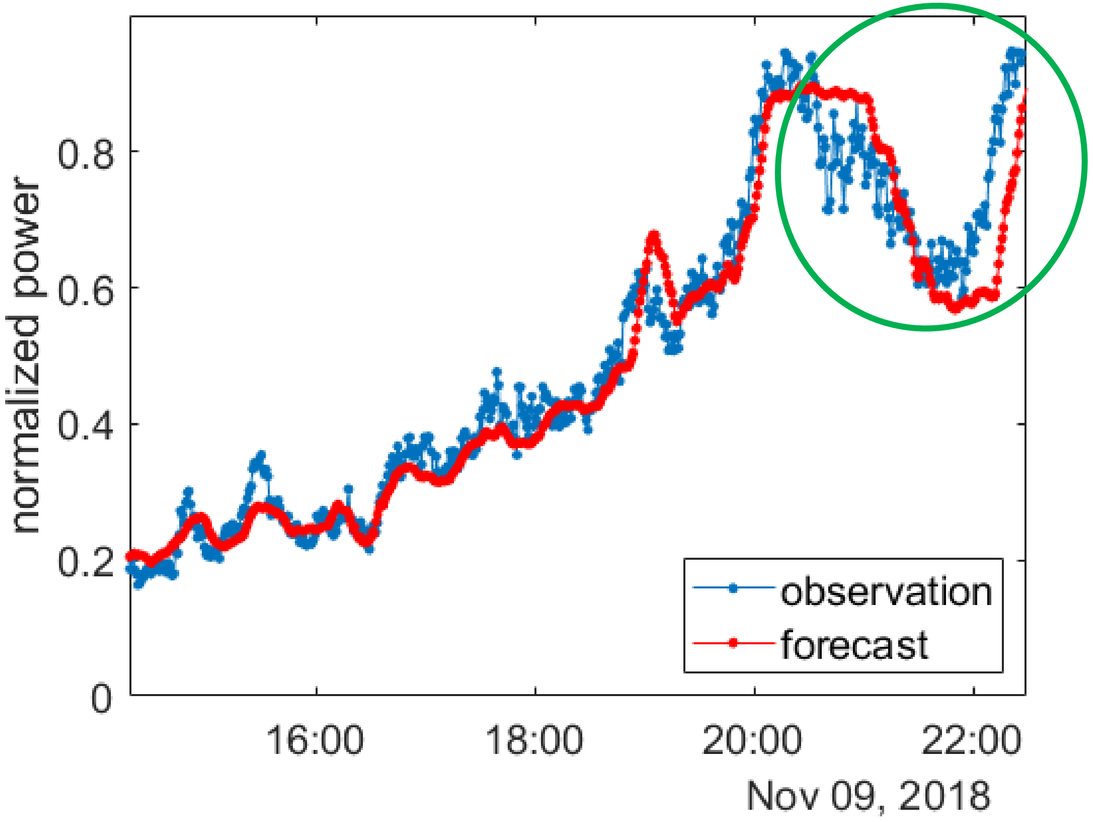

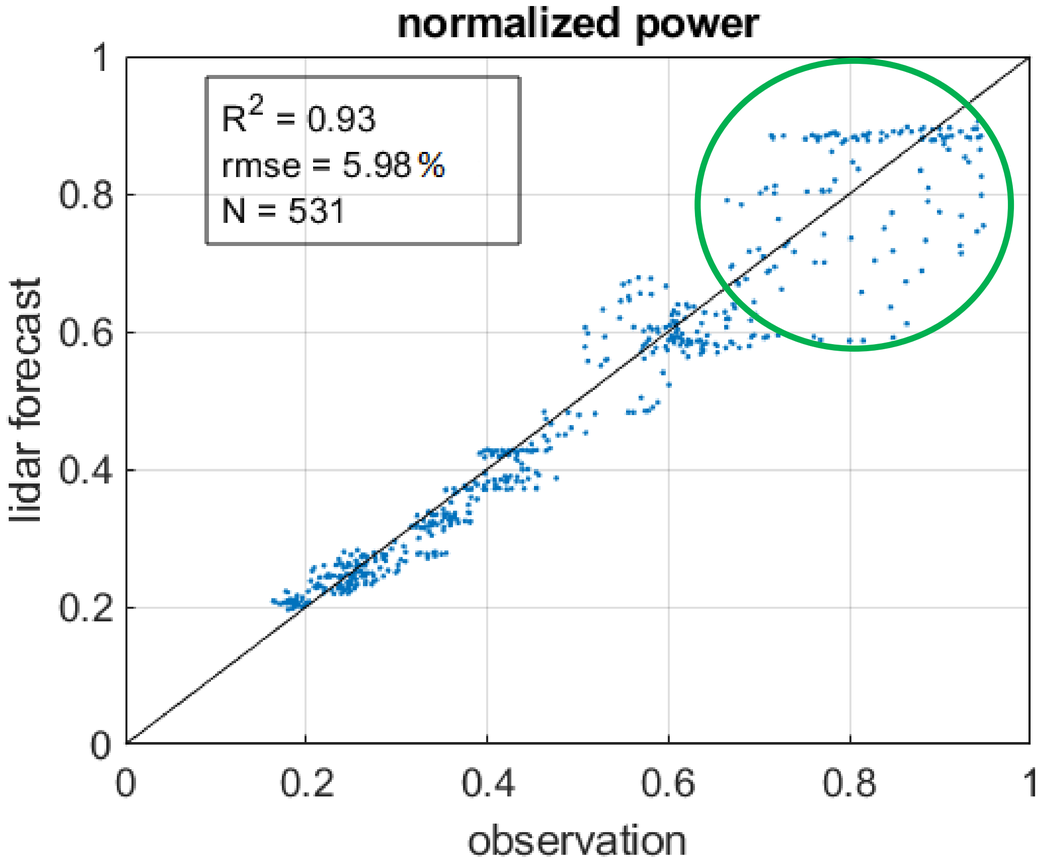

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Conclusion

Can horizontal long range lidar measurements be used to forecast power with lead times of 5-15 minutes?

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→ Yes!

- Lidar forecast outperforms the benchmark persistence
- The applied method limits the forcast‘s ability to predict fluctuations
- The availability of the forecast is strongly dependent on wind speed and turbine position

Outlook

- Optimize scan set-up
- Extend the forecast horizon
- Develop a probabilistic forecast
- Extend the forecast to the whole wind farm

Acknowledgements

The lidar measurements and parts of the work were performed within the research project "OWP Control" (FKZ 0324131A) funded by the German Federal Ministry for Economic Affairs and Energy on the basis of a decision by the German Bundestag.

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Questions?